E. T. CHILD.

CONTROLLING ELECTRICAL CIRCUITS.

APPLICATION FILED DEC. 21, 1907.

994,976. **Patented June 13, 1911.**

4 SHEETS—SHEET 1.

Fig. 2

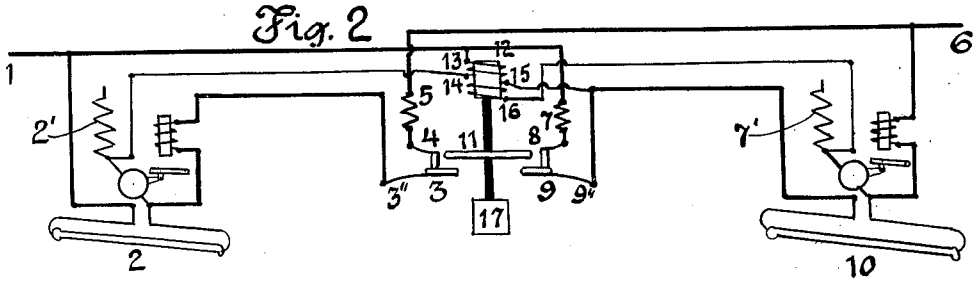


Fig. 3

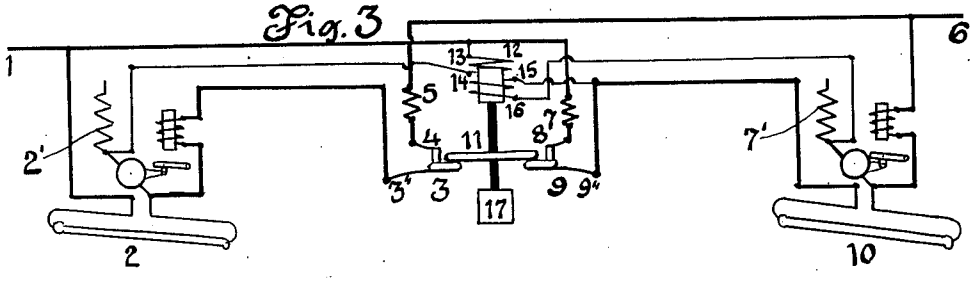


Fig. 4

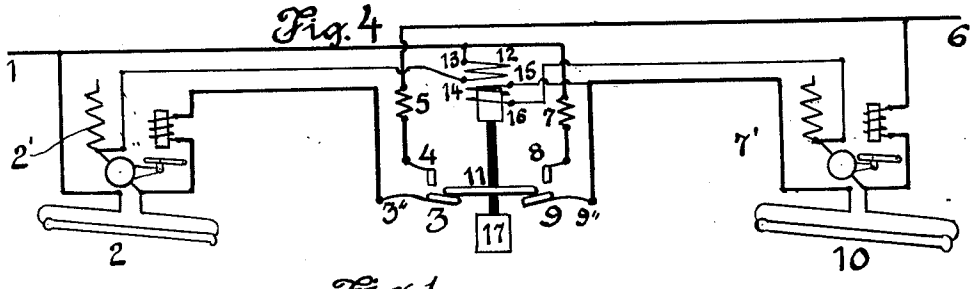
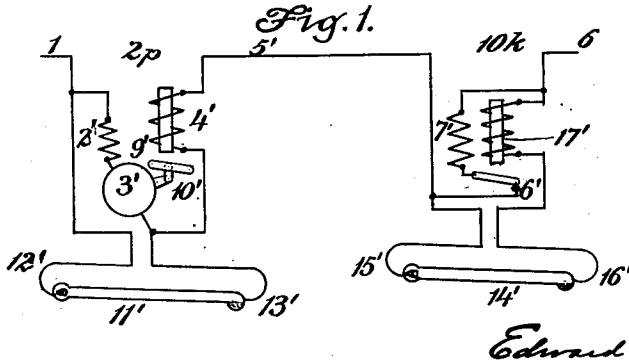


Fig. 1.



Witnesses

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4 SHEETS—SHEET 2.

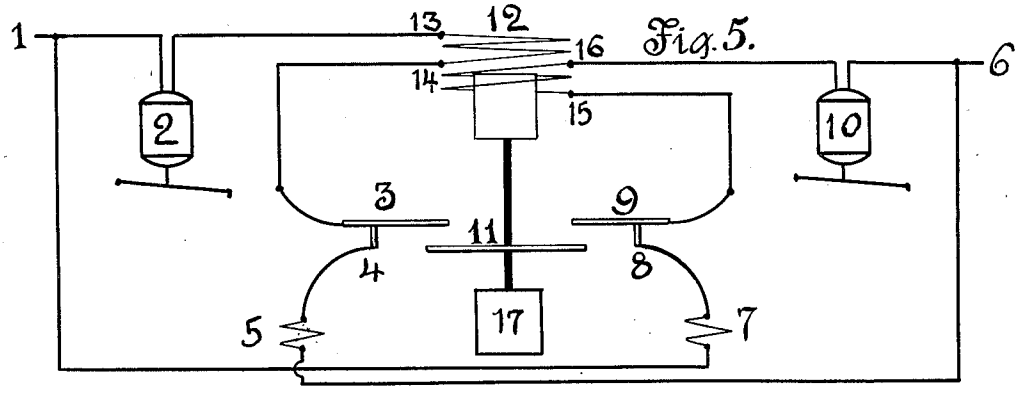

Fig. 5.

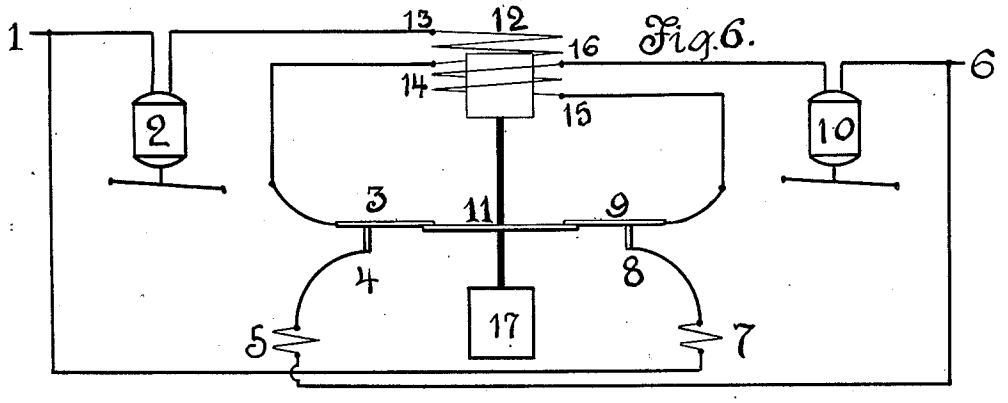

Fig. 6.

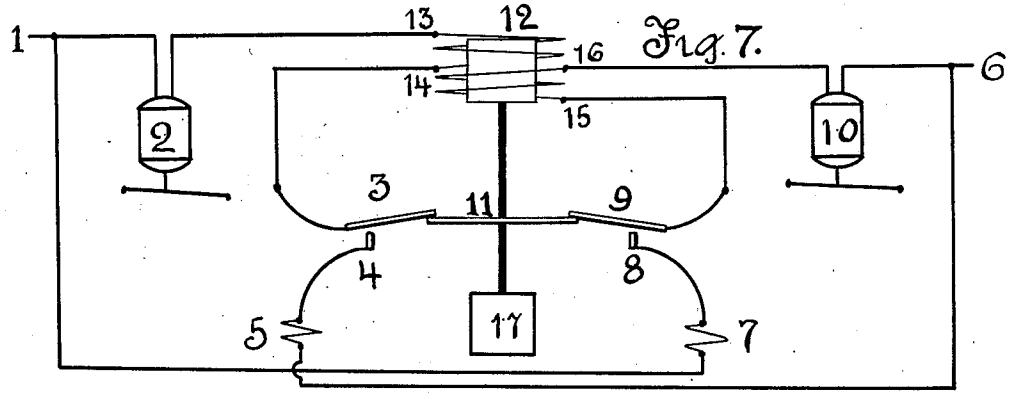

Fig. 7.

Witnesses

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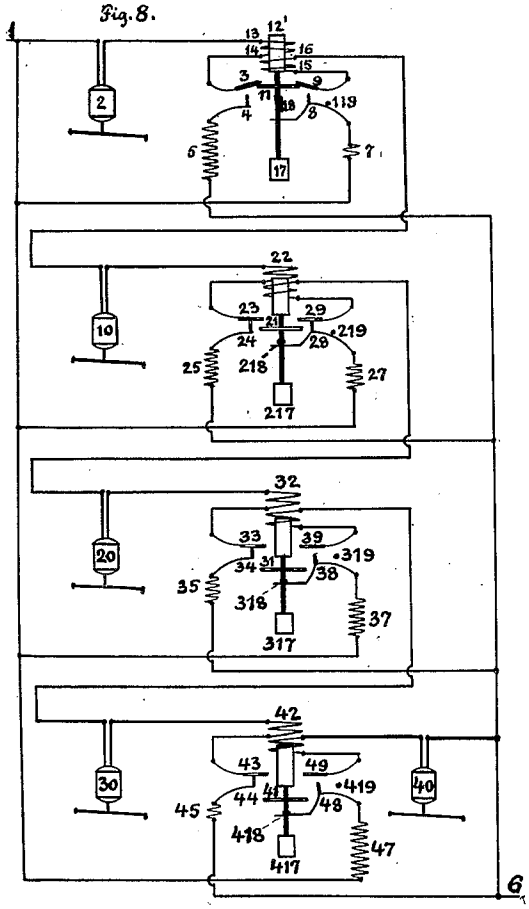
994,976. **Patented June 13, 1911.**

4 SHEETS—SHEET 3.

Fig. 8.



Witnesses

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APPLICATION FILED DEC. 21, 1907.

994,976. Patented June 13, 1911.

4 SHEETS—SHEET 4.

Fig. 9.

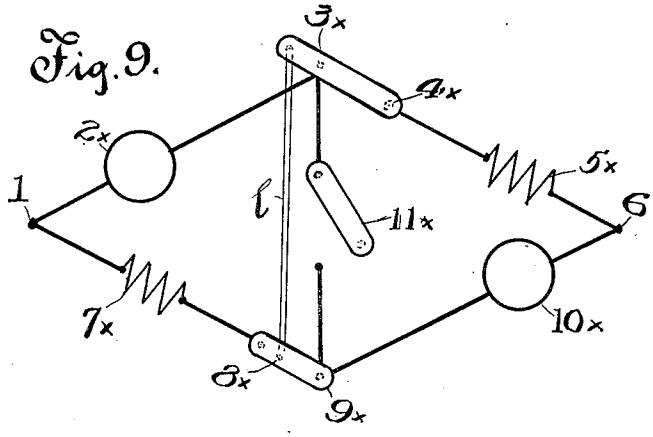


Fig. 10.

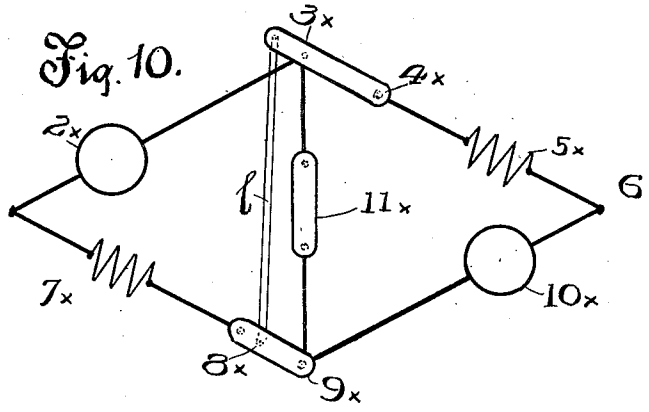
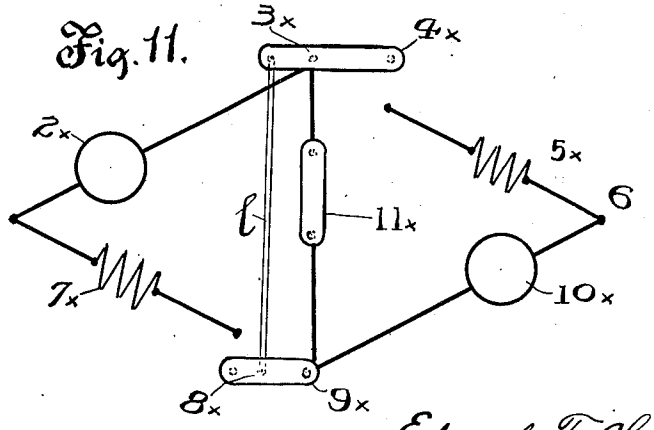


Fig. 11.



Witnesses

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UNITED STATES PATENT OFFICE.

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CONTROLLING ELECTRICAL CIRCUITS.

994,976. Specification of Letters Patent. Patented June 13, 1911.

Application filed December 21, 1907. Serial No. 407,482.

To all whom it may concern:

Be it known that I, EDWARD T. CHILD, a citizen of the United States, and a resident of Rosemont, Delaware county, Pennsylvania, (whose post-office address is post-office box 222, Rosemont, Pennsylvania,) have invented certain new and useful Improvements in Controlling Electrical Circuits, of which the following is a full, clear, and complete disclosure.

My invention relates broadly to the controlling of electric circuits and particularly has reference to the controlling of circuits containing apparatuses in which it is sometimes desired to operate various pieces of apparatus or mechanism in parallel and sometimes in series.

In changing a circuit used for controlling various kinds of apparatus from a series to a parallel connection arrangement and conversely from a parallel connection to a series arrangement, so far as I am aware, the current through some of the various pieces of apparatus is broken at the time of the change and although the actual time consumed in breaking and again closing the current may be very short, nevertheless there is always a shock to the apparatus at the time of the change, which shock naturally produces undue wear and tear upon the machines. Again, there are some kinds of apparatuses in which, if the current be once broken after the machine or apparatus is started, the apparatus will become inoperative and cease to perform its functions, for instance, in the case of mercury vapor lamps. If a current be once started through the apparatus, say with the apparatus in parallel and it is then desired to throw the various lamps into series, if the current be broken at the time of change from parallel to series, or conversely from series to parallel, they will become extinguished and will not relight. Moreover, with such lights, it is always necessary to have at least a predetermined voltage in order to enable the lamps to be kept lighted after having been once started.

The objects of my invention are to provide such an arrangement of circuits and to so control the same, that various pieces of apparatus located in the circuit may be changed from series to parallel and from parallel to series without substantially changing or varying the amount of current passing through the said apparatuses.

A further object of my invention is to provide means whereby apparatus, arranged to operate at a voltage less than the voltage of the main circuit, may be changed from a parallel to a series arrangement or conversely from a series to a parallel arrangement without substantially changing the current or the voltage of the current passing through said apparatus.

A further object of my invention is to operate various pieces of electric apparatus, in parallel and to change or control the current of said apparatus so that it will pass through the same in series without substantially changing the current passing through each piece of apparatus by substituting for each of the various pieces of apparatus a useless resistance and conversely by putting the electric apparatus out of series without changing the current through the essential part of the apparatus by substituting useless resistance for useful apparatus.

A further object of my invention is to so arrange various pieces of apparatus in a circuit so that the current through the apparatus may be changed through any less part than the whole number of pieces of apparatus in the series from parallel to series and from series to parallel without affecting the operation of the other pieces of apparatus.

A further object of my invention is to operate various pieces of electric apparatus and to control the current of said apparatus so that after one or more pieces of said apparatus are started in series with useless resistances, useful apparatus may be substituted for the said useless resistances without substantially changing the current through the first mentioned piece or pieces of apparatus.

A further object of my invention is to construct a switch which is especially adapted for use in connection with an electrical system in which it is desired to change the electrical relation or arrangement of various parts of mechanisms or apparatus in the circuit.

A further object of my invention is to provide an automatic lock for a circuit closer so that the arrangement of the various pieces of apparatus in the circuit cannot be easily changed or disturbed after once adjusted until certain predetermined conditions have been complied with.

A further object of my invention is to provide, arrange and connect a plurality of

pieces of electric apparatus so that, although started in parallel, they may be consecutively, one after the other, thrown into series without changing the amount of current passing through each piece of apparatus.

A further object of my invention is to improve and control the operation of the various switches by which circuits may be changed so as to run apparatus in parallel or in series without changing the current passing through each piece of apparatus so as to insure the simultaneous breaking of the circuits at the desired place.

A further object of my invention is to so electrically connect a plurality of mercury vapor lamps that they may be started and operated efficiently in a circuit of higher voltage than that for which the lamps were designed.

A further object of my invention is to automatically start a plurality of mercury vapor lamps in parallel and then to automatically change the arrangement from parallel to series without extinguishing the lamps.

A further object of my invention is to so arrange a plurality of mercury vapor lamps electrically connected so that some may be started automatically and some may be manually started or operated without effecting the operation of the others.

A further object of my invention is to provide means whereby a plurality of pieces of electrical apparatus may be so arranged in the circuit as to be automatically changed either from multiple to series, or from series to multiple when predetermined conditions are complied with in the running or operation of the pieces of the apparatus.

Further objects of my invention will be described in the claims and specification below.

In the drawings, forming a part of this application, in which the same part is indicated by the same reference letters throughout the various views, Figure 1 indicates one form of my invention as applied to mercury vapor lamps, one of which is automatic and the other hand operated. Figs. 2, 3 and 4 show an arrangement and system whereby all the lamps in the circuit are of the automatic or self lighting type. Figs. 5, 6 and 7 are an arrangement of circuits and automatic switches, formed in accordance with my invention and operating conversely to the arrangement shown in Figs. 2, 3 and 4. Fig. 8 illustrates my invention as applied to a circuit or system including more than two lamps. Figs. 9, 10 and 11 show a further diagrammatic arrangement illustrating the way in which the various pieces of electrical apparatus are changed from a series to a parallel or from parallel to a series, without changing the current.

In the operating of electrical apparatus it is frequently desired to run one portion, or part or piece of the apparatus on a circuit higher than that for which it is designed, as for example to run an electric lamp suitable for use on a 110 volt circuit, on a circuit of 220 volts, and this is usually accomplished by putting into the circuit an amount of resistance in series with the apparatus sufficient to cut down the potential to the desired point. This procedure however involves the waste of electric energy amounting in the above example to 50% of the energy supplied. If, therefore, several pieces of apparatus designed to operate on a circuit of low voltage are to be run on a circuit of high voltage it is much more efficient to arrange them in series with each other than to connect them up in series with a resistance. Further, some pieces of electrical apparatus when connected in series will not start properly since one will choke or interfere with the other and my invention has particular reference to such class of apparatus. Some mercury vapor electric lamps are an illustration of such a type of apparatus. These lamps consist essentially of two glass tubes partly filled with mercury. The longer tube is intended to give the light and the shorter tube is merely a shifter, and by its movement, which may be effected either by manual or mechanical means, it serves to start an arc in the longer tube. In such lamps the starting tube is made of a size that only one ampere of current passes through it, while three and one-half amperes are required by the larger tube, in other words the lamps require only one ampere of current to start them and three and one-half amperes of current to run them. Moreover, since it is practically impossible to make the change from one ampere to three and one-half amperes at the same instant in several lamps, it is impossible to arrange such lamps in series, since they will not start.

Lamps of the above character, designed to operate with a low voltage, can be used in a circuit with higher voltage by arranging the same in parallel with each other and wasting a great deal of electrical energy by inserting resistance to cut down the voltage. By my invention a plurality of the lamps may be arranged in series or with other electrical apparatus, and the lamps will run continuously and will be operated efficiently.

My invention is particularly applicable to mercury vapor lamps and other lamps of a similar type, and I have used the term "mercury vapor lamp" throughout this specification and the claims merely to typify that class of electric lamps in which an arc is maintained in a rarefied space containing a metallic or other suitable element in gaseous form, and do not consider it limited

to that class in which mercury is the metallic element.

Referring first to the form of my invention illustrated in Fig. 1, 2_p indicates a self lighting lamp and 10_k indicates a mercury vapor lamp of the tilting type. The current flows from the positive terminal 1 through the resistance 2′, the tube or shifter 3′, the electromagnet 4′, the lead 5′, the switch 6′ and the resistance 7′ to the negative terminal 6. This causes the electromagnet 4′ to lift its armature 9′ which by means of the link 10′ tilts the shifter 3′ breaking a mercury contact therein so as to start an arc in the tube 11′. The current now no longer flows through the shifter 3′ but from the terminal 1 through the wire 12′ to the tube 11′ in which it makes a brilliant arc to the wire 13′, thence through the electromagnet 4′, lead 5′, switch 6′ and resistance 7′ to the terminal 6. It will be seen from the above that the resistance 7′ is a useless or wasteful resistance which serves to cut down the voltage and make the proper amount of current pass through the tube 11′. The vapor lamp 10_k may now be started by merely tilting the tube 14′ by hand or otherwise, and an arc will be established in it which enables the current going through the wire 5 to flow through the wire 15′, tube 14′, wire 16′ and electromagnet 17′ to the negative terminal 6, but in so traversing the circuit the electromagnet 17′ will open the switch 6′ so that no current flows through the resistance 7′, but instead all the current flows through the tubes 11′ and 14′ thus illuminating the lamps. It often happens, however, that these mercury vapor lamps are located in inaccessible places and that it is inconvenient and difficult to manually tilt or start the same. Figs. 2, 3 and 4, therefore, show my invention as applied to a plurality of lamps of the self-lighting type. In this form of my device the current flows from the positive terminal 1 through the self-lighting 110 volt mercury vapor lamp 2, the contact points 3 and 4 and the resistance 5 to the negative terminal 6. The resistance 5 is great enough to cut down the current to the right voltage for operating the said lamp, that is to say, it cuts the voltage down to 110, although the difference in potential between the points 1 and 6 is much greater, as for instance 220 volts. The current also flows through the resistance 7, which resistance is made equal to the resistance 5, thence through the contact points 8 and 9 and the self-lighting 110, volt lamp 10 to the terminal 6. Both lamps are, therefore, arranged in parallel between the terminals 1 and 6 and will light properly and work on a 220 volt circuit, although they be 110 volt lamps, and they will take each their full amount of current, which in the common form of lamp now in use is three and one-half amperes for each lamp. One-half the energy is however wasted through the resistances 5 and 7. This condition is illustrated in Fig. 2. If, now the contact piece 11 be brought down until it touches the extended ends of the contact points 3 and 9 it forms an electrical connection between them but substantially no current will flow through the said connection, since the potential of the points 3 and 9 is substantially equal. This condition is illustrated in Fig. 3. If now, however, the contact piece 11 continues to move downwardly it will carry the contact points 3 and 9 with it, since the same are mounted upon spring arms 3″ and 9″ respectively and will break simultaneously the contact between the points 3 and 4 and the points 8 and 9, as illustrated in Fig. 4. The current now flows from the terminal 1 through lamp 2, contact point 3, piece 11, contact point 9 and lamp 10 to the terminal 6, and both lamps will remain lighted but the useless or wasteful resistances 5 and 7 will be cut out. The lamps 2 and 10 will be kept burning with an expenditure of only the amount of current required for one of them. The contact piece 11 thus forms a single means for simultaneously breaking the circuits composed of the lamps and the resistance and placing the lamps in series.

It is obvious that the contact piece 11 may be operated by hand but my invention contemplates the operation of the same by electrical means as well, and the structure is indicated diagrammatically in Figs. 2, 3 and 4, as follows: The contact piece 11 is attached to but insulated from the armature of an electromagnet 12. When there is no current flowing between the terminals 1 and 6 the contact piece 11 and the armature will fall in the position shown in Fig. 4. The electromagnet 12 is provided with two sets of windings, the terminals of one of which are 13 and 14, and the terminals of the other 15 and 16. When the current flow through the windings 13 and 14 the electromagnet 12 will lift the contact piece 11 and the current flowing through 15 and 16 will also lift the contact piece. If now the terminals 13 and 14 be connected with the starting circuit of the lamp 2 so that the current in the starting circuit will lift the contact piece 11 and the terminals 15 and 16 be connected with the starting circuit of the lamp 10, such current in this starting circuit will also lift the contact piece. As soon as the current is turned on the lamps it will flow in the starting circuits of both lamps and the combined action of the coils 13—14 and 15—16 which replace the resistance 2′ and 7′ respectively of Fig. 1 will lift the armature to its highest position, as shown in Fig. 2. After both lamps have been properly lighted no more current flows

through the starting circuit of either, and consequently there is no current in the electromagnet 12 and the contact piece 11 will fall by its own weight to the position shown in Fig. 3, and will continue its movement to the position shown in Fig. 4. The rise and fall of the contact piece 11 may be regulated by means of a suitable brake or dash pot 17. Whenever the lamps are situated at some distance from each other or when for any other reason it is undesirable to connect the electromagnet 12 with both starting circuits, the coil of the electromagnet 12 may be connected with only one of the starting circuits, *e. g.*, coil 13—14 may take the place of the resistance in the starting circuit of lamp 2, said resistance occupying a similar position in lamp 2 to that occupied by resistance 2′ in lamp 2_p in Fig. 1, it being only necessary that the dash pot or brake 17 operates sufficiently slowly to give the lamp 10 time to light before the contact is broken at 3—4, 8—9. Even if lamp 2 should light before lamp 10 the brake will retard the action of the switch so the lamp 10 will have time to light before the starting resistances are cut out, but should it at some time not light before the circuit is broken, both lamps will be extinguished. This will cause the current to flow again in the starting circuits and the contact piece 11 will again be raised and the whole operation will be repeated indefinitely until both lamps are lighted.

While I have described my invention as applied to a circuit in which the lamps are of equal resistance, it is obvious that my invention is just as applicable to a system in which the lamps or pieces of apparatus are of unequal resistance, so long as the combined resistance of the various pieces of apparatus is sufficient to bring the voltage down to the required point. In the case of pieces of apparatus of different resistances the resistance 7 must be made equivalent to the resistance of the piece of the apparatus 2, and the resistance 5 equivalent to the resistance of the apparatus 10. Another way of accomplishing the same result is to arrange the contact apparatus in the reverse manner to that illustrated in Fig. 2, as is illustrated in Figs. 5, 6 and 7. In this modification the electromagnet 12 has two windings with terminals 13 and 14 and terminals 15 and 16 respectively. When there is no current flowing the apparatus is in the position indicated in Fig. 5. When the current is turned on it flows from positive terminal 1 through lamp 2 to terminal 13 into the electromagnet 12 and out again at the terminal 14 through contact points 3 and 4 and the resistance 5 (equivalent to the resistance of lamp 10) to the negative terminal 6. The current also flows through positive terminal 1 and resistance 7 (equivalent to resistance of lamp 2) contact pieces 8 and 9 into the terminal 15 of the electromagnet 12 and out again through terminal 16 and through the lamp 10 to terminal 6. The electromagnet 12 is so made that it is strong enough to lift the contact piece 11 only when the full current is running through the two lamps.

In the case of the common type of lamp, above referred to, there would need to be three and one-half amperes flow through the terminals 13—14 and three and one-half amperes through the terminals 15—16. Consequently the apparatus remains in the position shown in Fig. 5 until both lamps, 2 and 10 are lighted. When, however, the arc is struck in both lamps the electromagnet 12 will lift the contact piece 11 until it touches the extended parts of the contact points 3 and 9, as shown in Fig. 6 and will continue to lift the contact piece 11 until the contact points 3 and 9 have been moved away from the contact points 4 and 8 to the position shown in Fig. 7, in which case both lamps are running in series and will continue so to run until something interrupts the current in one of them when the electromagnet will no longer be able to hold up the contact piece 11 which will fall to the position shown in Fig. 5 until both lamps are again lighted.

Any of the foregoing arrangements and modifications may be extended to cover the use of more than two lamps or pieces of apparatus in a series. It is thought, however, that one example will suffice to show how this may be done, and what additional points are to be considered in applying my system to a plurality of lamps in series. Thus for instance, the form of apparatus illustrated in Fig. 5 could be so extended as to use five one-hundred volt lamps in series in a five-hundred volt circuit as follows, reference being had to Fig. 8: Current flows from positive terminal 1 through lamp 2 and through the terminal 13 of the electromagnet 12 to the terminal 14, and thence through contact points 3 and 4 through four units of resistance 5 to negative terminal 6, these four units being sufficient to allow a 100 volt lamp 2 to be used in the 500 volt circuit, or the difference of potential between terminals 1 and 6. Attached to the armature of the electromagnet 12, and below the contact piece 11 is a button 118 pressing against an insulated extension of the contact point 8 and holding it away from the contact point 9. Electromagnet 12 is of such a strength that when the lamp 2 is lighted, the current flowing through it will be sufficient to raise the armature carrying the button 18 so far that the contact point 8 will touch the contact point 9. The contact point 8 is mounted on a spring, which will assist the electromagnet 12 in lifting the

armature. After the contact point 8 touches the contact point 9, its support will come against the stop or pin 119 so that it can rise no higher, and the electromagnet 12, with the current from only one lamp flowing through it, must not be strong enough to lift the armature 112 and the button 118 any higher, nor to bring the contact piece 11 up to where it touches the extensions of contact points 3 and 9. This condition is shown in Fig. 8, in the relation of the positions of contact points 28 and 29, button 218 and contact piece 21. As soon as contact point 8 touches contact point 9, the current will flow from positive terminal 1 through one unit of resistance 7, contact points 8 and 9 to the electromagnet 12 through the terminals 15 and 16, and thence to the lamp 10 and through the lamp and electromagnet 22, contact points 23 and 24, and three units of resistance 25 to negative terminal 6. Lamp 10 will light and its full current flowing through electromagnet 12 will cause contact piece 11 to be brought up into contact with contact points 3 and 9, and to lift them from the contact points 4 and 8, the current will then flow through lamps 2 and 10 in series, together with three units of resistance 25. In the meantime, the current through electromagnet 22 will be sufficient to enable it to lift the button 218, so as to allow contact point 28 to touch contact point 29, but no farther. The current will flow from positive terminal 1 through two units of resistance 27, contact points 28 and 29, electromagnet 22, lamp 20, electromagnet 32, contact points 33 and 34, and two units of resistance 35 to negative terminal 6. This current will enable magnet 22 to lift the contact piece 21 so as to touch the contact points 23 and 29, and lift them away from the contact points 24 and 28, and the current will flow through lamps 2, 10 and 20 in series with two units of resistance 35. This current will enable electromagnet 32 to allow the contact points 38 and 39 to engage starting a current through lamp 30, after which the electromagnet 32 will lift contact piece 31 to touch the contact points 33 and 39, and lift them away from the contact points 34 and 38, when the current will flow through lamps 2, 10, 20 and 30 in series. The current will now cause electromagnet 42 to allow the contact points 48 and 49 to engage starting the current through the lamp 40, after which the electromagnet 42 lifts the contact piece 41 against the contact points 43 and 49, and lifts them away from the contact points 44 and 48, when all the current will flow through the five lamps in series with all useless resistance cut out. This whole operation will be accomplished without consuming at any one time more than about twice the normal amount of current required for one lamp, but when it is not important to limit the amount of starting current, the buttons 118, 218, 318 and 418 may be omitted.

Thus it will be seen from what has gone before that the principle involved in all the foregoing forms of my invention is the same, the difference being merely one of selection of that arrangement by which the current is provided with a path through useful apparatuses as a substitute for a path through wasteful starting resistances. This principle also comprises the change in the circuit containing a plurality of pieces of apparatus and a plurality of useless resistances, of a change in the arrangement of the same from series to parallel or from parallel to series without any interruption or change in the current passing through the parts of the apparatus in which the change is not being made. This arrangement is especially useful in connection with machines as distinguished from stationary apparatus, inasmuch as the shock and wear upon the machine as the current is broken, just before the change from series to parallel or parallel to series is always considerable, no matter how short a period is required to actually make and again break the circuit. I do not wish to be understood, however, as implying that the shock to apparatus may not be just as undesirable as a shock to the machine at the time of the break just before the change. In almost every instance this shock would be objectionable and my invention overcomes these objections inasmuch as the current is never broken; its path is merely changed. I do not wish, therefore, to have my invention understood as being limited to a system containing mercury vapor lamps as the principle which is embodied in my invention is capable of adaptation to a large variety of uses, *e. g.* trolley car circuits.

In Figs. 9 to 11 inclusive, I have attempted to show in the simplest diagrammatic manner the broad principle and operation of my invention. In said figures, 2^{x} represents one piece of electric apparatus and 10^{x} a second piece of apparatus arranged in parallel between the terminals 1 and 6 of an electric circuit and it is desired to connect 2^{x} and 10^{x} in series without any interruption of the current in either. Resistance 5^{x} is placed in the circuit with 2^{x} and the resistance of 5^{x} should be equivalent to the resistance of 10^{x}, the other machine. In like manner, resistance 7^{x} should be located in the branch of the circuit in series with the machine or apparatus 10^{x} and the amount of resistance of the coil 7^{x} should be equal to the resistance of the machine 2^{x}. Two switches 3^{x} and 9^{x} respectively are arranged to coöperate with terminals 4^{x} and 8^{x} respectively and are connected by a suitable link as L^{x} to work simultaneously. Between the switches 3^{x} and 9^{x}, is connected a third

switch 11^x which corresponds to the contact piece 11 of Fig. 2. When the currents are closed through the terminals 1 and 6, it flows equally through the machines 2^x and 10^x since the resistance of the two structures of the parallel arrangement are equal if then the switch 11^x be closed, no current will pass between the points 3^x and 9^x since the potentials of each of the parallel circuits is equal at this point. Such a condition is shown in Fig. 10. If now the switches 3^x and 9^x be simultaneously opened the current through the machines 2^x and 10^x will not be interrupted but will merely take the path through 11^x, the condition being shown in Fig. 11 and both pieces of apparatus will be in series with each other without useless or unnecessary resistance in the current and without any interruption of the current in either.

Other embodiments of my invention will be apparent from the above disclosure to those skilled in the art and I therefore do not wish to be construed as limited to the exact constructions shown, since any embodiment of my device which falls within the scope of the appended claims is fully contemplated by me.

Having thus fully described my invention, what I claim and desire to protect by Letters Patent of the United States is:

1. In an electrical system, a plurality of pieces of electrical apparatus in parallel in a circuit and a single means actuated by the current in said circuit for changing the arrangement of said pieces from parallel to series without substantial change in the current in said pieces.

2. In an electrical system, a plurality of pieces of electrical apparatus in a circuit and a single means actuated by the current in said circuit for changing the arrangement of said pieces from parallel to series and from series to parallel without substantial change in the current in said pieces.

3. In an electrical system, a plurality of pieces of electrical apparatus arranged in parallel in a circuit, each of said pieces having a resistance in series therewith, and a single means actuated by the current in said circuit for changing the arrangement of said pieces from parallel to series, and simultaneously cutting out said resistances from said circuit.

4. In an electrical system, a plurality of pieces of electrical apparatus in a circuit, each of said pieces having a resistance in series therewith, and a single means actuated by the current in said circuit for changing the arrangement of said pieces from parallel to series and from series to parallel, and simultaneously interchanging the resistances and the pieces of electrical apparatus in said circuit.

5. In an electrical system, a plurality of circuits arranged in parallel, each containing a piece of electrical apparatus and a resistance in series therewith, and a single means actuated by the current in said circuits for simultaneously cutting out said resistances from said circuits and changing the arrangement of said circuits from parallel to series.

6. In an electrical system, a plurality of circuits arranged in parallel, and each containing a piece of electrical apparatus and a resistance in series therewith, and a single means actuated by the current in said circuits when predetermined conditions have been fulfilled for simultaneously cutting out said resistances from said circuits and changing the arrangement of said circuits from parallel to series.

7. In an electrical system, a circuit of a predetermined voltage, a plurality of pieces of electrical apparatus designed to operate at a lower voltage than the voltage of said system, and a single means for automatically changing the arrangement of said pieces in said circuit from parallel to series and from series to parallel without substantial change in the current in said pieces.

8. In an electrical system, a circuit of a predetermined voltage, a plurality of pieces of electrical apparatus designed to operate at a lower voltage than the voltage of said system, arranged in parallel therein with compensating resistances, and a single means for automatically cutting out said resistances and changing the arrangement of said pieces from parallel to series.

9. In an electrical system, a plurality of open circuits, each containing a piece of electrical apparatus and a resistance, said circuits being arranged in parallel, means actuated by closing certain of said circuits for consecutively closing the remaining circuits, and means for changing the arrangement of said circuits from parallel to series.

10. In an electrical system, a plurality of pieces of electrical apparatus, and means for consecutively changing the arrangement of each piece of apparatus in the circuit from parallel to series without substantially changing or interrupting the circuit in said apparatus.

11. In an electrical system, a plurality of pieces of electrical apparatus requiring a comparatively low voltage, a circuit of higher voltage than that required for any one of said pieces, means to put various pieces of said apparatus in series with resistances and in parallel with each other to maintain a low voltage through said pieces of apparatus, and means to simultaneously and automatically cut out said resistances and throw said pieces into series with each other without substantially interrupting or changing the current in said apparatus.

12. In an electrical system, a pair of pieces of electrical apparatus arranged in parallel

circuits, a resistance in each of said circuits equal to the resistance of the piece of apparatus in the other circuit, means to automatically connect points of equal voltage in said circuits, and operated only after both pieces are in proper operation, and means for subsequently automatically cutting out said resistances.

13. In an electrical system, a pair of terminals, a pair of parallel circuits connected to said terminals, a piece of electrical apparatus and a resistance in series in each circuit, said resistance in each circuit being equal to the resistance of the apparatus in the other circuit, means for automatically bridging said parallel circuits between the resistances and the pieces of apparatus after said pieces of apparatus are in proper operation, and means for simultaneously breaking the circuit between said resistances and said terminals.

14. In an electrical system, a plurality of pieces of electrical apparatus arranged in parallel in a circuit, and means to automatically and simultaneously change the arrangement of said pieces from parallel to series without substantial change in the current in said apparatus.

15. In an electrical system a plurality of pieces of electrical apparatus, and means for automatically changing the arrangement of said pieces in the circuit from parallel to series without substantially changing the current in said apparatus.

16. In an electric lighting system, a plurality of mercury vapor lamps arranged in parallel, each lamp having a resistance in series therewith, and means for consecutively changing the arrangement of said lamps from parallel to series and simultaneously cutting out said resistances.

17. In an electrical system, a plurality of open circuits, each containing a piece of electrical apparatus and a resistance, and means actuated by closing certain of said circuits for consecutively closing the remaining circuits in parallel with the preceding circuits, each resistance being equal to the combined resistance of the succeeding pieces of apparatus.

18. In an electrical system, a plurality of open circuits, each containing a piece of electrical apparatus and a resistance, means actuated by closing certain of said circuits for consecutively closing the remaining circuits in parallel with the preceding circuits, each resistance being equal to the combined resistance of the succeeding pieces of apparatus, and means actuated by the current for changing the arrangement of said circuits from parallel to series, without substantial change in the current through each piece of apparatus.

19. In an electrical system, a plurality of open circuits, each containing a piece of electrical apparatus and a resistance, means actuated by closing certain of said circuits for consecutively closing the remaining circuits in parallel with the preceding circuits, each resistance being equal to the combined resistance of the succeeding pieces of apparatus and means actuated by the current for consecutively changing the arrangement of said circuits from parallel to series, without substantial change in the current through each piece of apparatus.

20. In an electrical system, a plurality of pieces of electrical apparatus arranged in parallel in a circuit, and means operated by closing the circuit through one of said pieces for changing the arrangement of said pieces from parallel to series without substantial change in the current through said pieces.

21. In an electrical system, a plurality of pieces of electrical apparatus arranged in a circuit and means operated by the current through said pieces for changing the arrangement of said pieces from parallel to series when both are in proper operation, and from series to parallel should either cease proper operation, without substantial change in the current through said pieces.

22. In an electrical system, a plurality of pieces of electrical apparatus arranged in parallel in a circuit, each of said pieces having a resistance in series therewith, and means operated by the current through said pieces for changing the arrangement of said pieces from parallel to series and simultaneously cutting out said resistances from said circuit, without substantial change in the current through said pieces.

23. In an electrical system, a plurality of pieces of electrical apparatus arranged in a circuit, each of said pieces having a resistance in series therewith, and means operated by closing the circuit through one of said pieces for changing the arrangement of said pieces from parallel to series and from series to parallel, and simultaneously interchanging said resistances and said pieces of electrical apparatus.

24. In an electrical system, a plurality of pieces of electrical apparatus arranged in parallel in a circuit, a resistance in series with each piece of apparatus, a switch between each resistance and the corresponding piece of apparatus, and means for engaging said switches to open the same simultaneously and to connect said pieces of apparatus in series.

25. In an electrical system, a plurality of pieces of electrical apparatus arranged in parallel in a circuit, a resistance in series with each piece of apparatus, a switch between each resistance and the corresponding pieces of apparatus, and a single contact piece for engaging the switches to open the same and to connect said pieces of apparatus in series.

26. In an electrical system, a plurality of pieces of electrical apparatus arranged in parallel in a circuit, a resistance in series with each piece of apparatus, a switch between each resistance and the corresponding pieces of apparatus, and a single contact piece having an electromagnet for actuating the same for engaging the switches to open the same and to connect said pieces of apparatus in series.

27. In an electrical system, a pair of mercury lamps arranged in parallel in a circuit, a resistance in series with each lamp, a switch between each resistance and its lamp, and means to open said switches simultaneously and to change the lamps from parallel to series.

28. In an electrical system, a pair of mercury lamps arranged in parallel in a circuit, a resistance in series with each lamp, a switch between each resistance and its lamp, and a contact piece to open both switches simultaneously and to change the lamps from parallel to series.

29. In an electrical system, a pair of mercury lamps arranged in parallel in a circuit, a resistance in series with each lamp, a switch between each resistance and its lamp, a contact piece, and an electromagnet having two separate windings connected respectively in the starting circuits of the lamps for actuating said contact piece to open said switches simultaneously and to change the lamps from parallel to series.

In witness whereof I have hereunto set my hand this 20th day of December, A. D. 1907.

EDWARD T. CHILD.

Witnesses:

ALSTON B. MOULTON,

ALEXANDER PARK.